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PORTABLE REFRIGERATION CHAMBERS FOR STUDYING COLD RESISTANCE OF PLANTS IN THE FIELD[1]

By J. R. HOLBERT, *senior agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture;* W. L. BURLISON, *chief in crop production, University of Illinois;* and A. G. JOHNSON, *principal pathologist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture*[2]

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INTRODUCTION

In studies of resistance of corn to cold it was found desirable to design and construct portable refrigeration chambers in which corn plants growing under natural conditions in the soil might be exposed to various temperatures for different periods. It is the object of this circular to describe this apparatus and its operation.

The apparatus consists of (1) the chambers proper, together with electric refrigeration units, coils, and controls; (2) the derricks, including hoists and tracks; (3) the sled; and (4) additional equipment necessary in moving and operating the apparatus.

DESCRIPTION OF APPARATUS

REFRIGERATION CHAMBER

In general, each chamber consists of a specially constructed refrigerator box open at the bottom so that it can be set down over the plants. General views of the chambers are shown in figures 1 and 2. A close view of the arrangement of the refrigeration units, the switches, and other electrical equipment on the instrument side of

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[1] Cooperative investigations by the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U.S. Department of Agriculture; the Illinois Agricultural Experiment Station; and the Funk Bros. Seed Co.

[2] Thanks are due J. W. Hardin, of the Division of Cereal Crops and Diseases, for performing the major part of the work of constructing the refrigeration chambers, derricks, and tracks and devising the best method of handling them.

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one of the chambers is shown in figure 3, and the details of construction are given in figures 4, 5, and 6.

It will be noted that the chamber has a heavy, strongly braced frame. This is necessary, as the fully equipped chamber is heavy, weighing more than 2 tons, and is subject to considerable torsion in handling. The chamber, therefore, must be strong and rigid to avoid cracking in the joints or elsewhere.

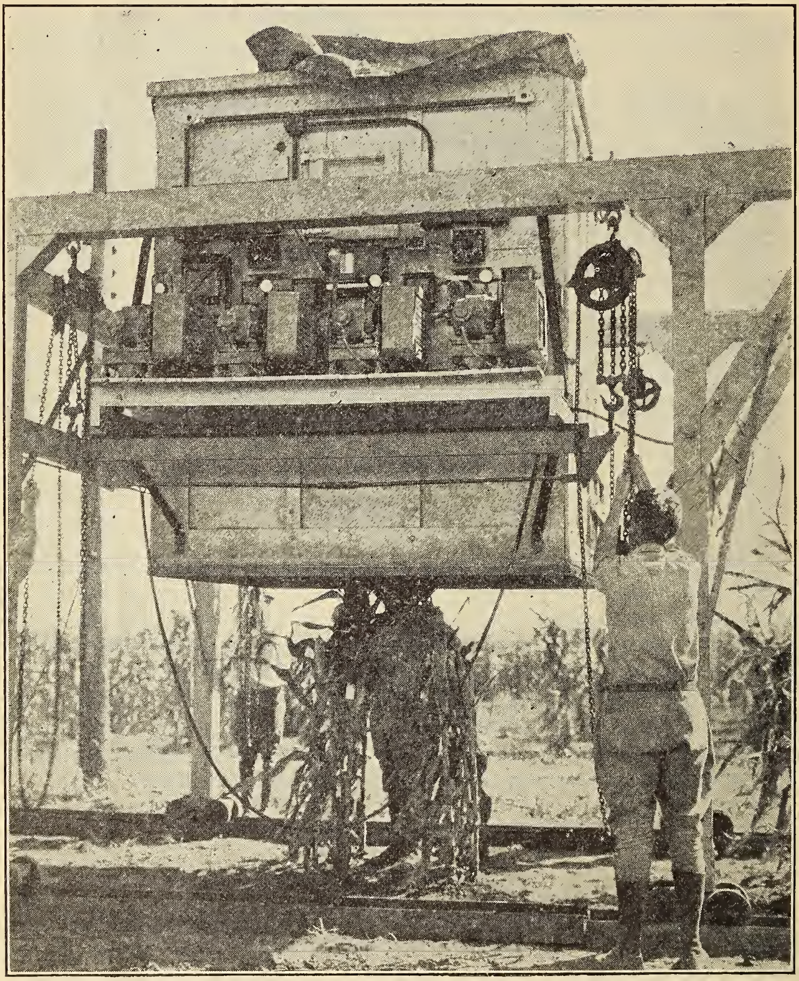


FIGURE 1.—Field refrigeration chamber being placed over four hills of corn.

As shown in figure 6, the walls and top are heavily insulated with cork, sealed in with hydrolene, and covered inside and outside with thick composition board (homosote). The top is covered with galvanized iron. All is kept heavily painted, both inside and outside.

Specially designed equalizers to which the hoists are attached are used on two sides of the chamber (figs. 1 and 4) for raising or lowering it.

Four electric refrigeration units are mounted on one side of the chamber (figs. 1 and 2). These refrigeration units have a combined refrigeration capacity equivalent to approximately 1,600 pounds of melting ice in 24 hours, so that low temperatures may be obtained and controlled as desired, even when there is considerable fluctuation in the outside temperatures.

The refrigeration coils are mounted on the side walls in the chamber (fig. 7). Baffle boards are placed inside the coils in order to protect adjacent plants and to secure convection currents of the air within the chamber to equalize the temperatures. Properly placed baffle boards with the aid of one or two small electric fans have been found sufficient to secure adequate air circulation and uniform temperatures throughout the chamber.

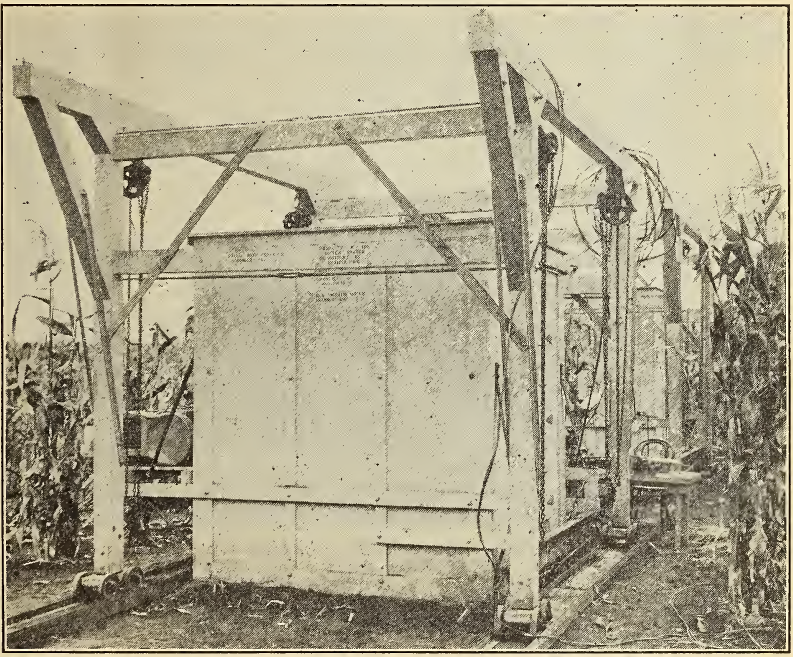


FIGURE 2.—Field refrigeration chambers in position for operation; soil banked against the base of the chambers to prevent leakage of cold air from the inside.

In the electric line to each refrigeration unit, different types of thermostats have been tried for controlling the operation of the individual refrigeration machines. The switch and bulb of one of the thermostats are shown in figure 3, *n*, and figure 7, *l*, respectively. This same chamber is equipped with another thermostat, figure 3, *o*, whose action depends on the pressure of the refrigerant in one of the refrigeration coils. The latter is capable of a finer adjustment than the former, but both are useful.

A small auxiliary refrigeration box, attached to the side of the chambers, is shown in figure 8. The inside dimensions of this box are 9 by 15 by 15 inches. By adjusting two valves on the side of the chamber (fig. 8, *c* and *d*) one of the refrigeration units may be made to cool either the small coil (fig. 8, *b*) in the auxiliary box (fig. 8, *a*) or one of the 4 large coils in the chamber (fig. 7). This auxiliary box is useful for making or preserving ice needed to maintain, at the desired temperature, the reference junction in the thermoelectric equipment and also to preserve samples in connection with studies of cold injury.

Only those machines have been employed in which methyl chloride is used as the refrigerant. Machines in which the refrigerant is carbon dioxide or some other gas not injurious to living plants would be satisfactory also, but those in which the refrigerant is sulphur dioxide or ammonia are not satisfactory because living plants are highly sensitive to these gases.

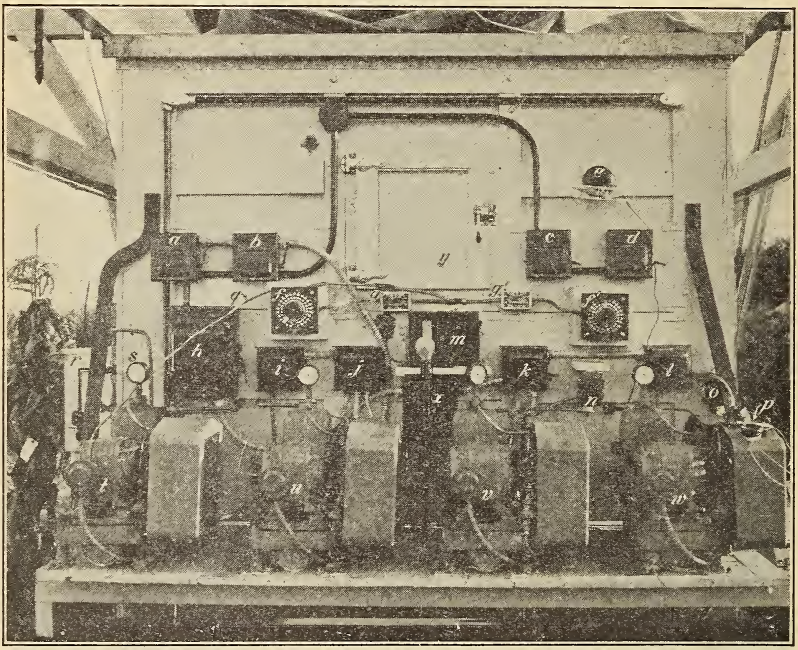


FIGURE 3.—Side of refrigeration chamber showing instruments: *a*, Light switch for front and side lights; *b*, light switch for lights above refrigeration units and other equipment; *c*, light switch for inside lights; *d*, switch for current operating electric fans on the inside of chamber; *e*, fan used occasionally to insure even temperatures of posts in switchboards, *f* and *f'*; *f* and *f'*, switchboards for iron-constantan leads, shown in figure 7, for measuring temperature by the thermoelectric method; *g* and *g'*, switches controlling circuit to switchboards *f* and *f'*; *h*, main switch for control of electric current; *i*, *j*, *k*, and *l*, individual motor switches for motors, *t*, *u*, *v*, and *w*, respectively; *m*, distance thermograph for recording temperature of air on inside of chamber; *n*, switch of thermostat in circuit operating motor *v*; *o*, switch of thermostat in circuit operating motor *u*; *p*, telephone; *q*, iron and constantan lead wires, incased in lead, connecting thermocouples in chamber with reference junction and potentiometer shown in figure 13; *r*, auxiliary refrigeration box on side of chamber, shown in figure 8; *s*, gage indicating head pressure of compressor; *t*, *u*, *v*, and *w*, motors operating individual refrigeration units; *x*, relay box; *y*, observation window.

DERRICK

The derrick is strong and well braced, as shown in figure 9. Each derrick post rests on a dolly pin which fits into a 4-wheel carriage, which, in turn, runs on a track, as shown in figures 1, 2, and 9. The

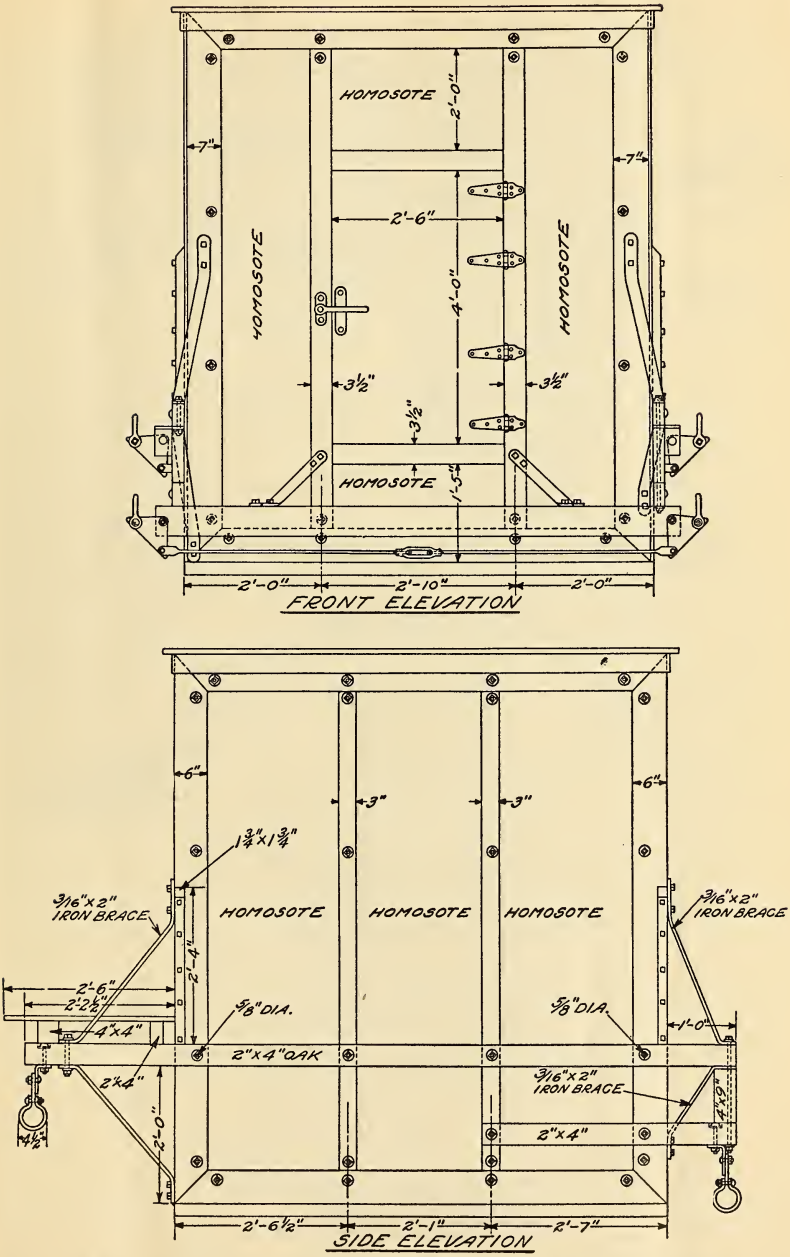


Figure 4.—Front and side elevations of field refrigeration chamber.

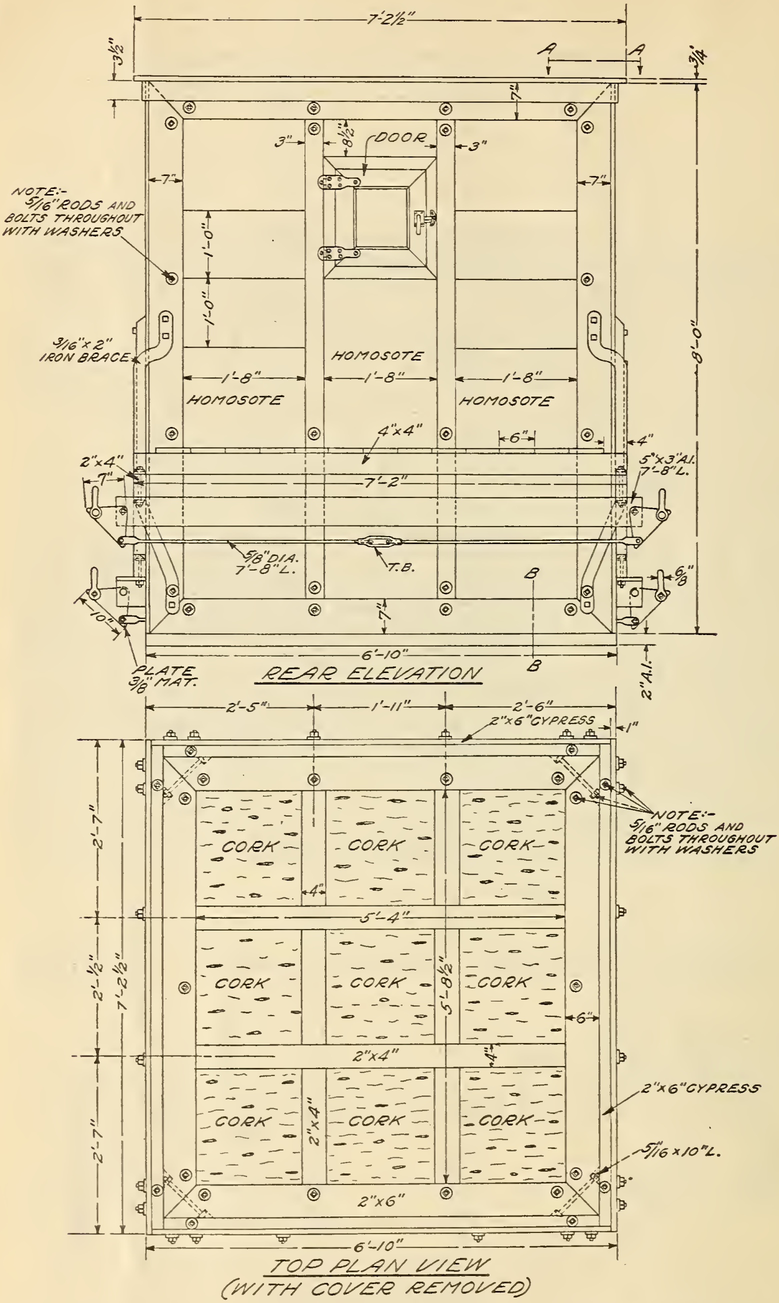
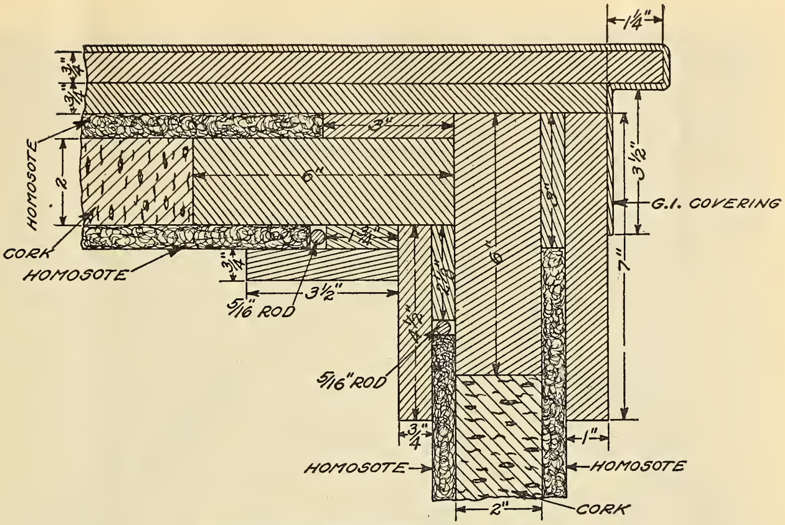
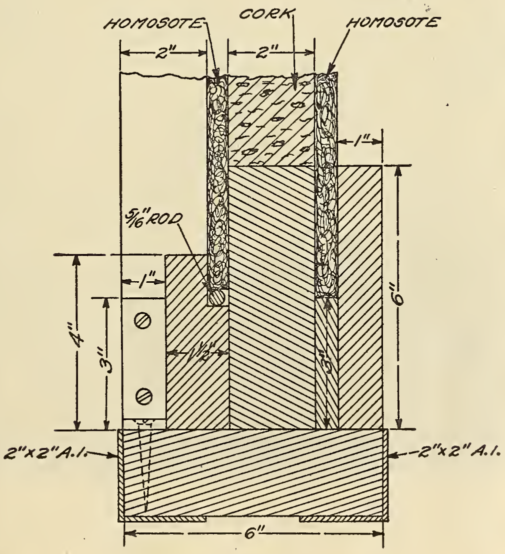


FIGURE 5.—Rear elevation and top plan of field refrigeration chamber: A, A and B, B, cross sections shown in figure 6; A.I., angle iron; DIA., diameter; L., length; MAT., material; T.B., turnbuckle.



CROSS SECTION A-A



CROSS SECTION B-B

Figure 6.—Cross sections of rear elevation (fig. 5, A, A and B, B), showing details of construction; A.I., angle iron; G.I., galvanized iron.

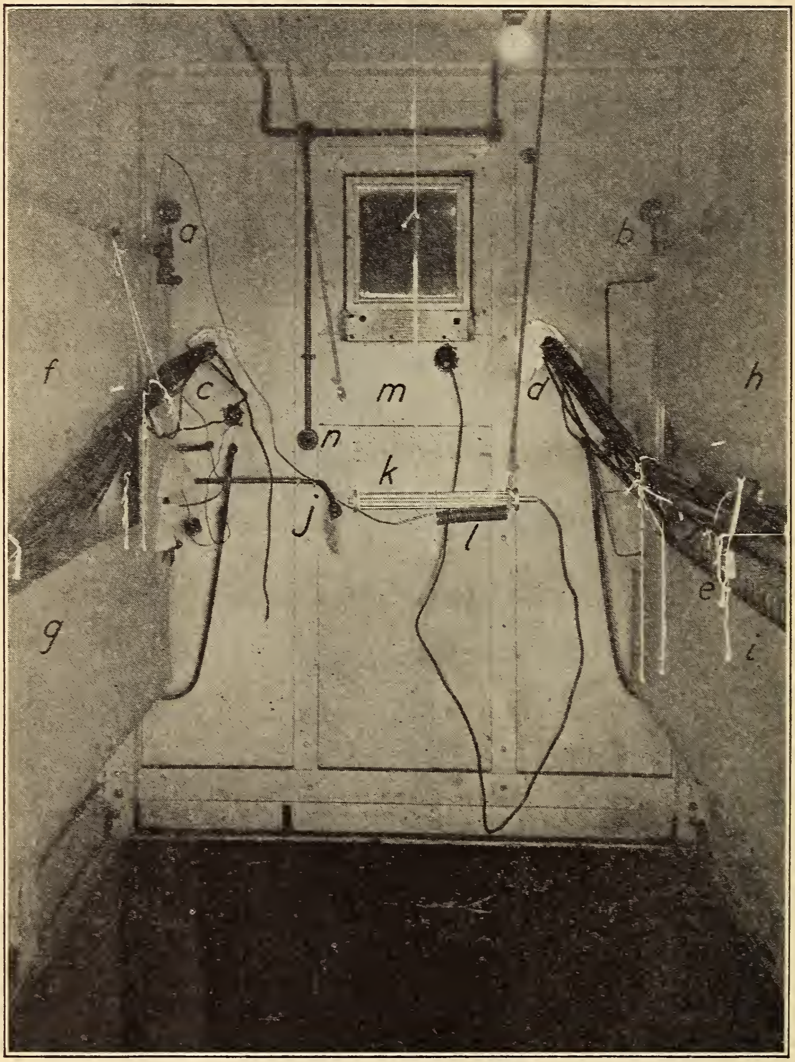


FIGURE 7.—Interior of field refrigeration chamber: *a* and *b*, Gages for indicating pressure of refrigerant in coils; *c* and *d*, iron and constantan lead wires from switchboards *f* and *f′* in figure 3; *e*, metal label on lead wires; *f*, *g*, *h*, and *i*, baffle board inside of coils to protect plants from coils and to aid in equalizing the inside temperature by means of convection currents; *j*, telephone connection; *k*, grid bulb for thermograph labeled *m* in figure 3; *l*, thermostat bulb for thermostat switch labeled *n* in figure 3; *m*, thermometer; *n*, plug-in for electric fan cord.

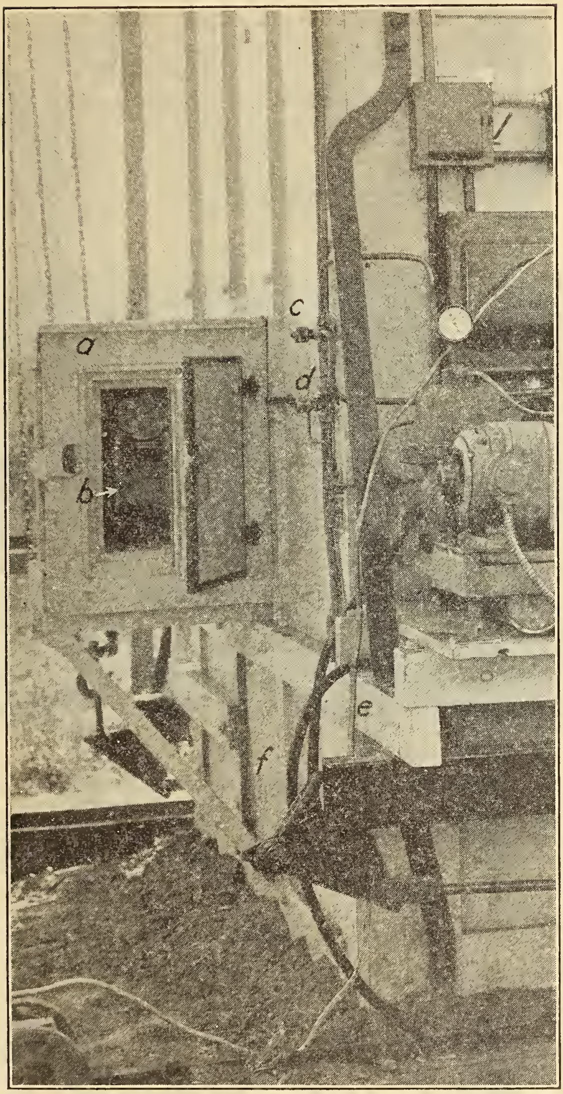
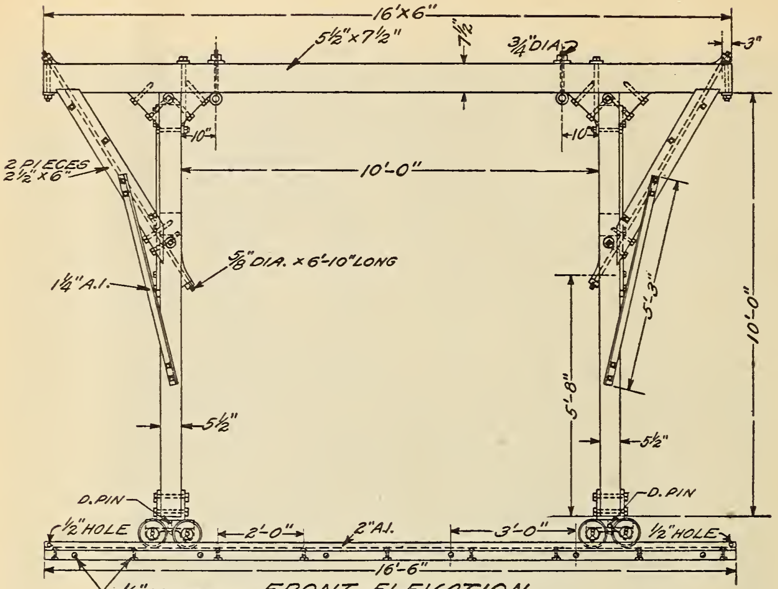
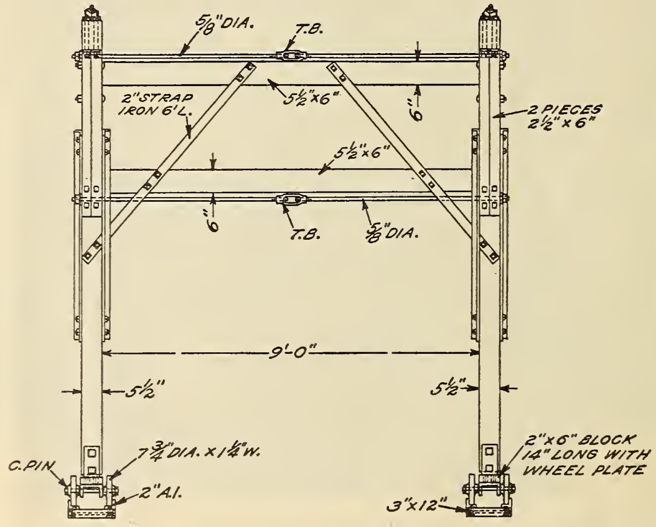


FIGURE 8.—Auxiliary refrigeration box shown in figure 3, *r,* on side of chamber: *a,* Auxiliary refrigeration box; *b,* coil on inside; *c* and *d,* valves used for turning refrigerant either into coil, *b,* inside of auxiliary refrigeration box, *a,* or into coil back of baffle board shown in figure 7, *i; e,* iron and constantan lead wires, incased in lead, shown in figure 3, *q; f,* rubber-insulated wires conducting electric current to chamber.



FRONT ELEVATION



SIDE ELEVATION

Figure 9.—Front and side elevations of derrick and track: A.I., angle iron; BOLTS C.S., bolts countersunk; C. PIN, cotter pin; DIA., diameter; D. PIN, dolly pin; L., length; T.B., turnbuckle; W., width.

dolly pins permit the carriages to follow the tracks and also to make right-angle or other turns.

Each derrick requires four screw chain hoists, each of 1-ton capacity, for lifting the chamber. These hoists are attached to the equalizers as shown in figure 1.

The track is made of planks, 3 by 12 inches, 16 feet long, with 2-inch angle irons on the top edges, as shown in figures 1, 2, and 9, to serve both as a guide and a track for the derrick carriages. For convenience in moving the track, a ½-inch hole is drilled in the angle irons, near each end, for inserting the hooks of a special handle, as shown in figure 10. Four pieces of track, that is, 4 planks, are required for each chamber; 2 are under the chamber and 2 loose ones are used for moving the chamber in any direction desired, as shown in figures 1 and 2.

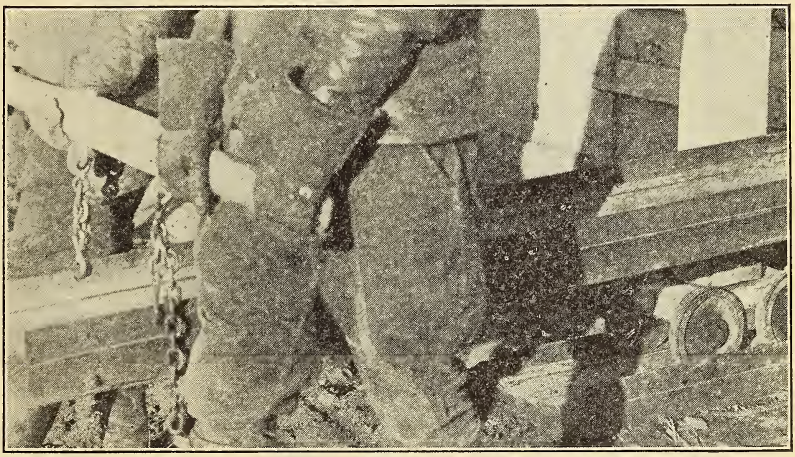


FIGURE 10.—Special handle for carrying track.

SLED

A large specially built sled is used for moving the chamber from one location to another in the same field, as shown in figure 11. This sled consists of 2 runners 8 by 12 inches, 10½ feet long; 5 cross pieces 3 by 10 inches, 9 feet long; and 11 planks 2 by 10 inches, 9 feet long, laid lengthwise for the top. The cross pieces are spaced equally and countersunk into the runners. The runners are faced with 20-gage galvanized iron on the front, bottom, and bottom edges. Two heavy pieces of strap iron are fastened to the inside of the front ends of the runners. Each of these was made from a piece of strap iron ⅜ by 4 inches, 3 feet long, and fastened to the runner by three ½-inch bolts. In the front end of each of these pieces of strap iron is a 2½-inch hole for attaching chains when the sled is pulled by a tractor (fig. 11, B and C).

ADDITIONAL EQUIPMENT

In addition to the chamber, with its electric refrigeration units, coils, and controls, the derrick, with the hoists and tracks, and the sled, it is necessary to have available a truck and tractor for moving the chambers and derricks. Thermographs, thermometers, and thermoelectric equipment are necessary for observing and recording the temperatures in the chambers, as well as in the plants themselves.

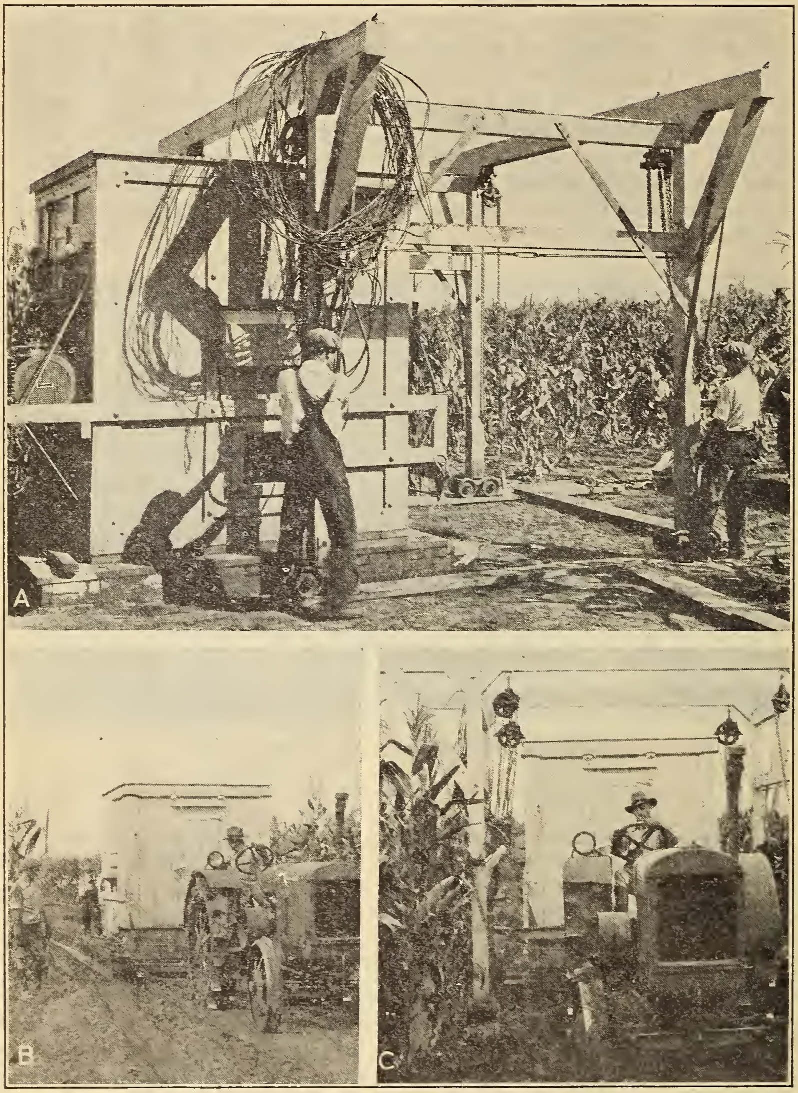


FIGURE 11.—Operations in moving chamber and derrick from one location to another in the same field: A, Chamber being lowered to sled, the hoists unhooked, and the derrick placed on tracks for moving; B, chamber, on sled, being pulled by tractor; C, chamber, under derrick, raised by hoists so that sled may be taken away, chamber lowered to ground, and tracks placed under derrick.

At least one thermograph with daily drum is necessary for each chamber. The type known as the distance-reading or soil thermograph is best. In this type the thermograph box may be placed on the outside of the chamber (fig. 3, *m*), where it may be conveniently watched, with only the bulb inside the chamber, as shown in figure 7, *k*. The bulb is placed midway between the plants. Only sensitive thermographs are satisfactory. Reliable and certified thermometers are placed in different locations in the chambers, near different parts of the plants, and their readings compared with each other and with the thermograph record.

Sensitive and reliable thermographs equipped with daily drums have been found desirable for recording natural drops in temperatures in the field during periods at which cold injury occurs. The temperature records thus obtained (fig. 12) are useful as guides in operating the chambers so as to duplicate, as nearly as possible, the natural drops in temperatures during nights on which cold injury has been known to occur.

Thermoelectric equipment is necessary for determining the air temperatures in different parts of the chambers close to the plant tissues and especially for determining the exact temperatures of the various plant tissues. From the switchboards on the instrument side of the refrigeration chamber, leads of iron-constantan duplex wire, gage 14, rubber-covered and braided, extend into the chamber, as shown in figure 7. Each of these leads carries two metal labels on which have been stamped a number corresponding to the number on the switchboard. One of the numbered labels is attached near the end of each lead and the other is attached to the same lead inside the chamber near the point where the lead enters the chamber. Two labels are used instead of one, so that if the label near the end of the lead is lost the lead may be identified readily by the other label and the lost label replaced. The thermocouples used in the refrigeration chambers are made from enameled iron and constantan wires, gage 38, each about 6 inches long, soldered to the corresponding rubber-insulated lead wires. A semiprecision potentiometer and the reference junction are located in a field laboratory near the experimental field plots, as shown in figure 13, A, *a*. Insulated duplex iron and constantan lead wires, incased in lead, connect the switchboards on the refrigeration chambers to the potentiometer in the field laboratory, as shown in figures 3, *q*; 8, *e*; and 14, *a*. The person who operates the potentiometer (fig. 13, A) has telephone connection with the person operating the switchboard (fig. 3, *f*, and fig. 13, B) and the electric refrigeration units. For recording the potentiometer readings and the corresponding temperatures, as well as other data, specially prepared sheets, 24 by 40 inches in size, have been found very convenient and useful (fig. 13, *f*).

Equipment for maintaining a reference junction at a temperature of 0° C. over a period of several hours is shown in figure 15. The extra insulation and the provision for draining off the warmer water from the bottom of the jug when it is necessary to add crushed ice are important features. Also, the large stopper makes it possible to insert several thermocouples, and also thermopiles, thus obviating the necessity for maintaining several independent reference junctions at the same time. It has been found advantageous to cool this heavily insulated jug thoroughly by placing it in a refrigerator for several hours prior to making up the reference junction for a night's run.

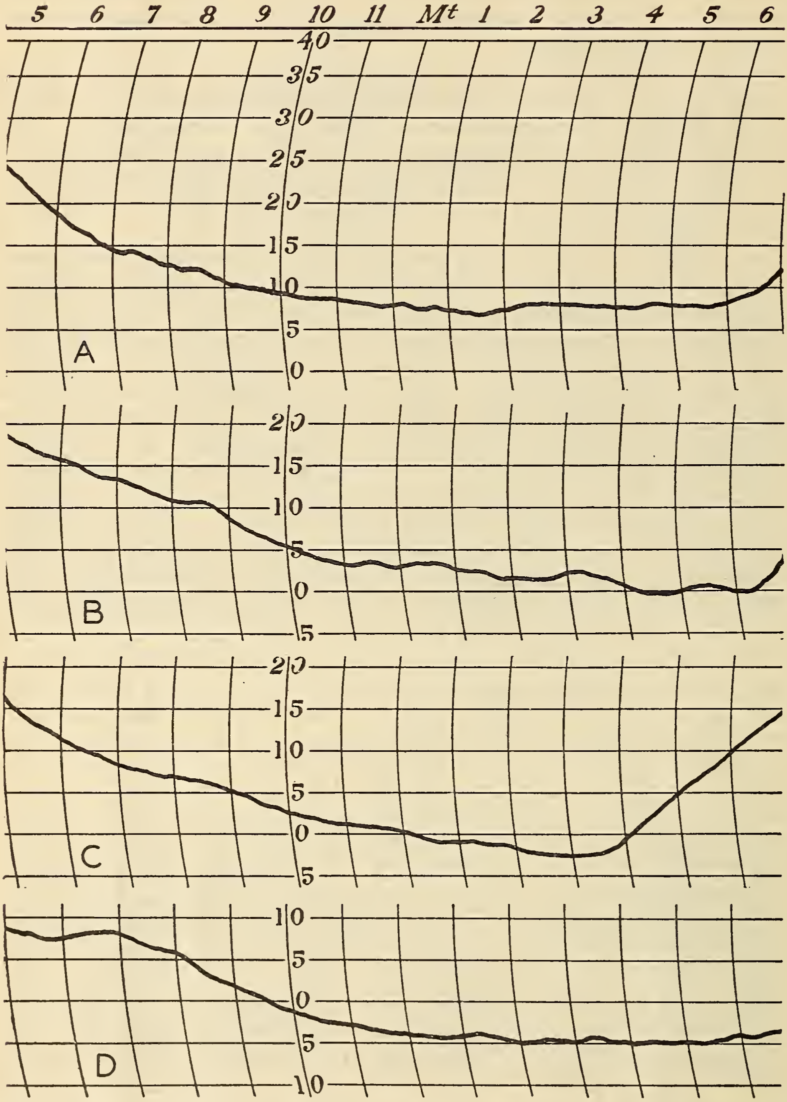


FIGURE 12.—Representative temperature records of nights in the fall of 1929 on which cold injury of different intensities occurred; A, Minimum temperature distinctly above 0° C.; B, minimum 0° for a short period; C, minimum temperature distinctly below 0° for a relatively short period; D, distinctly below 0° for a long period.

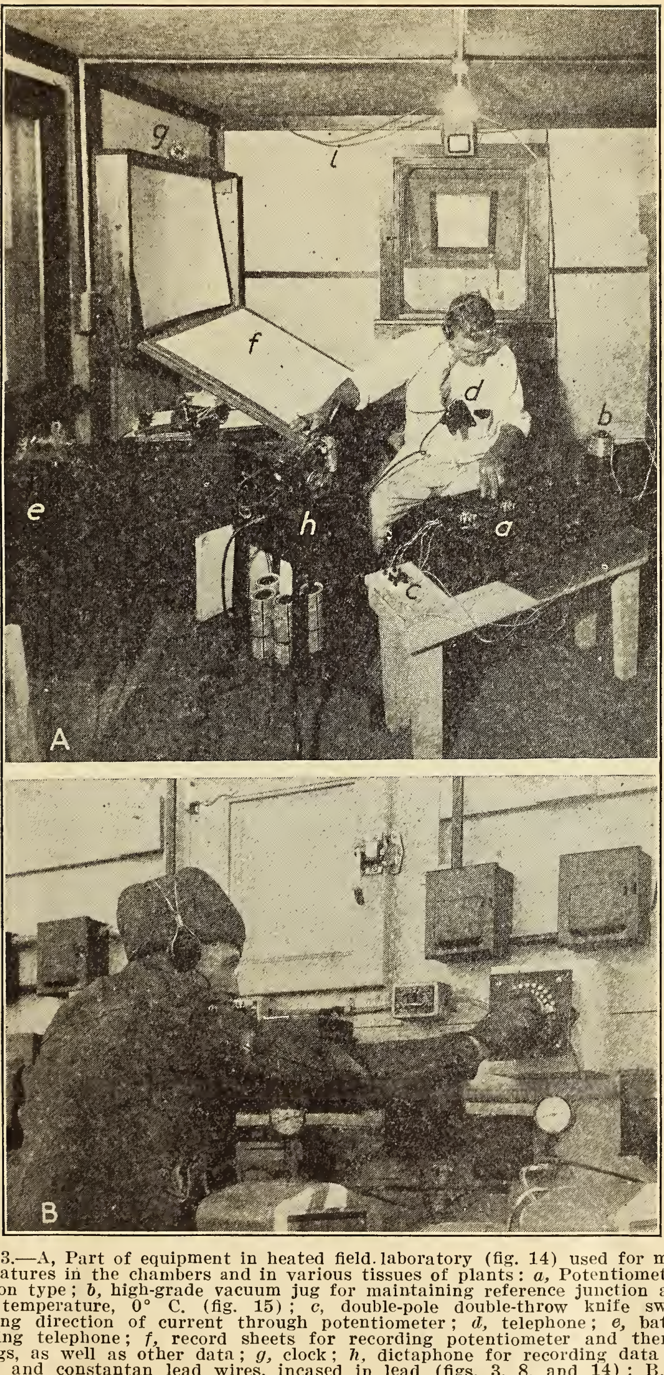


FIGURE 13.—A, Part of equipment in heated field laboratory (fig. 14) used for measuring temperatures in the chambers and in various tissues of plants: *a*, Potentiometer, semiprecision type; *b*, high-grade vacuum jug for maintaining reference junction at a constant temperature, 0° C. (fig. 15); *c*, double-pole double-throw knife switch for reversing direction of current through potentiometer; *d*, telephone; *e*, battery for operating telephone; *f*, record sheets for recording potentiometer and thermometer readings, as well as other data; *g*, clock; *h*, dictaphone for recording data rapidly; *i*, iron and constantan lead wires, incased in lead (figs, 3, 8, and 14); B, part of equipment on outside of chamber, the operator acting on telephoned directions from person operating potentiometer inside chamber.

In order to measure accurately the effects of chilling and freezing temperatures on plants, it is necessary to have comparable plants that have not been exposed to such temperatures. Greenhouse sashes, supported by framework, as shown in figure 16, have proved very useful in protecting the plants from chilling and even freezing temperatures during the nights of early fall. Tarpaulins thrown over the top and sides make such an arrangement more effective. Also, electric heaters inside have been used occasionally to good advantage. The sashes are removed from the framework during the daytime and replaced at night. Somewhat similar protection for young plants, to be used as unexposed controls, frequently is needed in the spring.

To protect the motors and other instruments on the chambers from exposure to the weather when not in use and from occasional rains and heavy dews, a special hood made from heavy canvas has been found very satisfactory. The hoods are wired to rings soldered to the galvanized-iron roof of the chamber (fig. 17). One man can cover or uncover the equipment, which is a decided advantage under some conditions. The chambers, including thermoelectric equipment, have been operated successfully even when a cold drizzling rain continued all night.

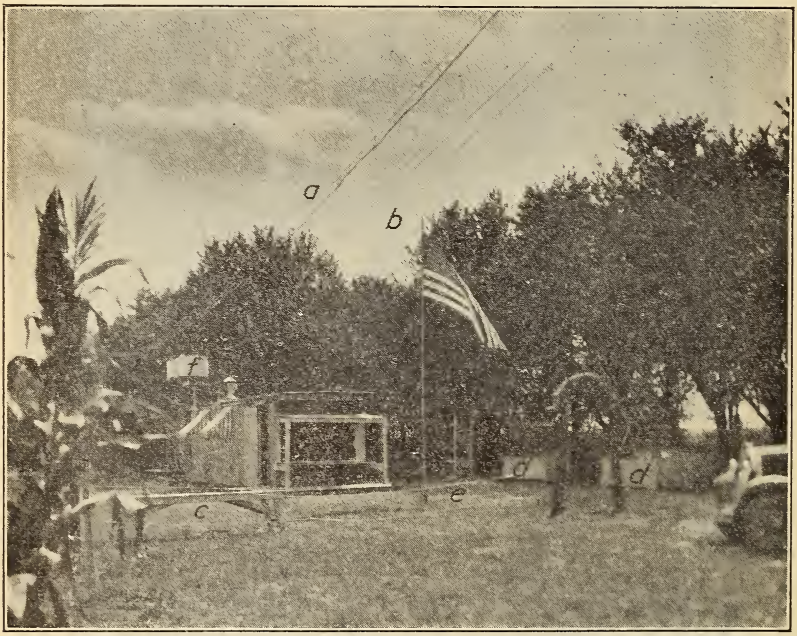


FIGURE 14.—Heated field laboratory and part of outside equipment: *a,* Iron and constantan lead wires, incased in lead; *b,* light wires; *c,* galvanized-iron covered table; *d,* field tool box; *e,* photographic frame; *f,* water tank.

In addition, it is necessary to have telephones and tools, and special equipment of various kinds, including planks, blocks, jacks, chains, tarpaulins, flashlights, drop cords, and ropes. In order to secure the best results, a heated field house and field tool boxes (fig. 14, *d*) are also essential.

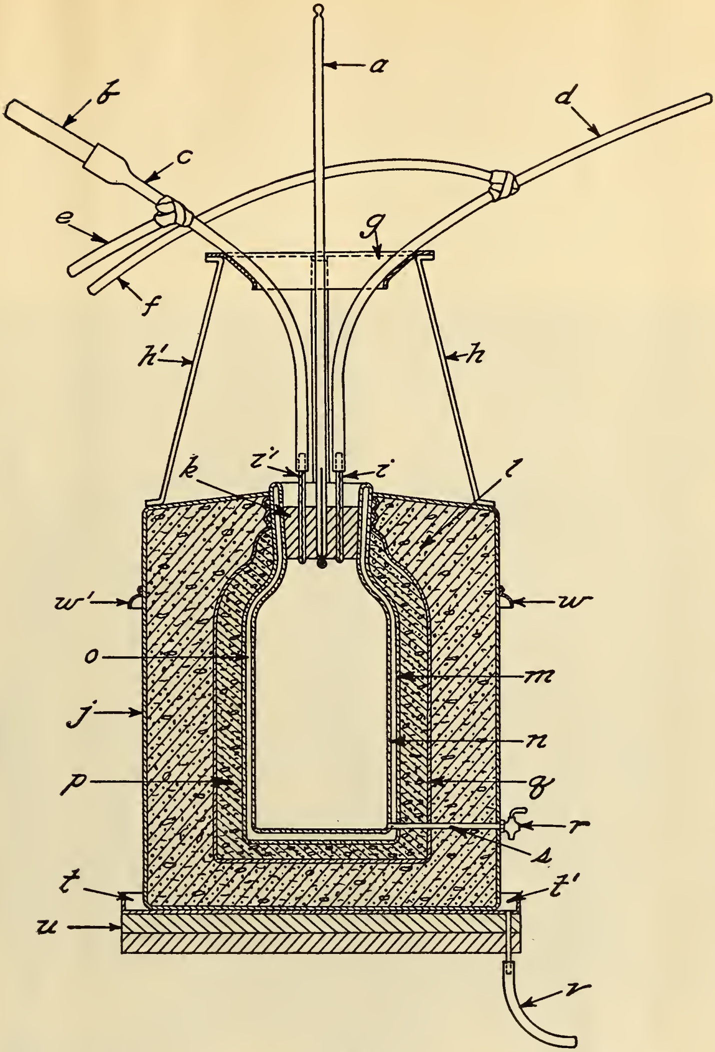


Figure 15.—Cross section of heavily insulated vacuum jug for maintaining a reference junction at a temperature of 0° C. over a period of several hours: *a*, Certified thermometer with neck of sufficient length so that 0° may be read conveniently without disturbing position of thermometer in stopper; *b*, insulated iron and constantan leads, incased in lead, leading to field refrigeration chambers (fig. 14, *a*); *c*, iron and constantan leads, 26 gage, insulated and incased in rubber tubing, leading to reference junction; *d*, thermopile cable, incased in rubber tubing, for use in physiochemical studies; *e* and *f*, leads to potentiometer; *g*, circular copper frame for supporting leads and thermopile cables and for protecting thermometer, supported by four standards, two of which are shown (*h* and *h'*), three fourths of an inch wide, made from heavy copper strips with turned edges for strengthening; *i* and *i'*, glass tubes in which the insulated iron and constantan leads are embedded in hard paraffin, the junction (or insulated junctions in case of thermopile) of these leads touching the very thin-walled ends of the tubes, which in turn are placed just under the surface of the ice slush in the jug; *j*, copper covering for ground cork insulation; *k*, stopper made of cypress wood, boiled in paraffin, with holes for reference junctions, *i* and *i'*, and thermometer (*a*); *l*, ground cork; *m*, outside wall of vacuum jug; *n*, inside wall of vacuum jug; *o*, partial vacuum between walls of vacuum jug; *p*, insulation between outside wall or jug and metal covering (*q*); *q*, outside metal covering of jug; *r*, faucet for withdrawing the warmer water from bottom of jug when ice is added at top; *s*, brass tube leading from inside of jug to faucet; *t* and *t'*, drain for catching overflow and drainage water; *u*, wooden base; *v*, rubber tubing for carrying away water from drain (*t* and *t'*); *w* and *w'*, handles.

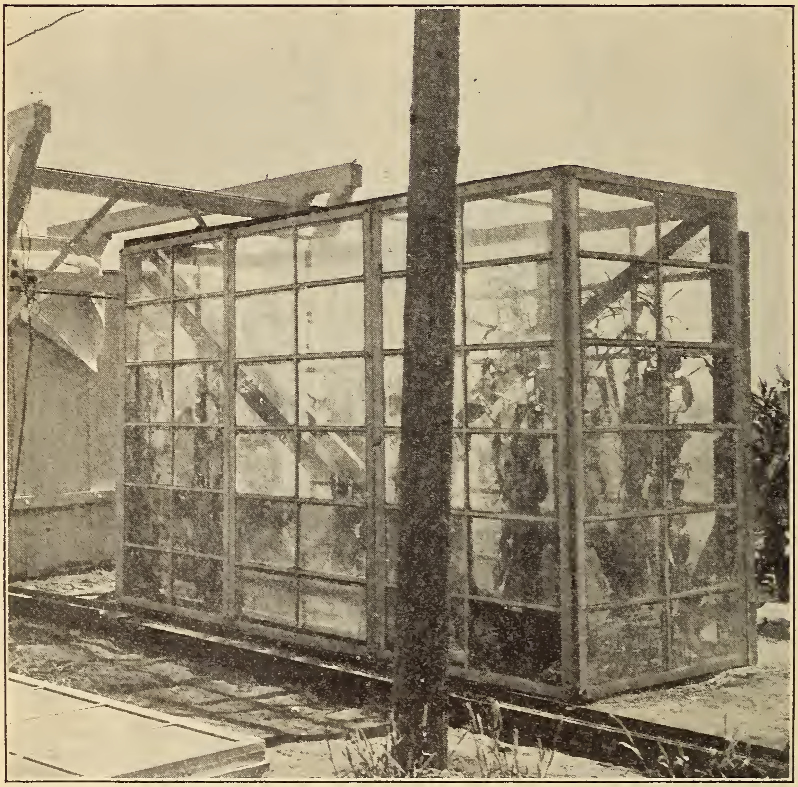


FIGURE 16.—Greenhouse sash supported on wooden framework and used at night to protect plants from injury from natural drops in temperature.

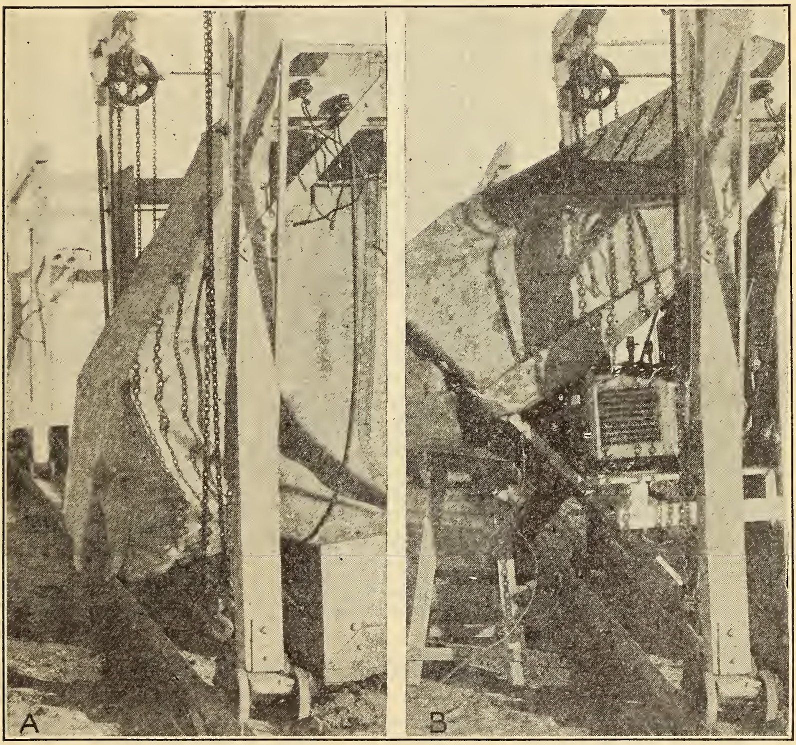


FIGURE 17.—Hood for protecting equipment mounted on side of chamber: A, Position of hood when chamber is not in use; B, position of hood during damp and rainy nights.

MATERIALS

A list of materials used in the construction of a single refrigeration chamber, derrick, track, and sled is given in table 1.

TABLE 1.—*Materials for an individual refrigeration chamber, derrick, track, and sled*

LUMBER

Description	Pieces or quantity	Size	Use
	Number		
No. 1 pine	2	8 by 12 inches by 12 feet	Sled.
Do	2	3 by 10 inches by 18 feet	Do.
Do	1	3 by 10 inches by 12 feet	Do.
Do	5	2 by 10 inches by 18 feet	Do.
Do	1	2 by 10 inches by 12 feet	Do.
Clear cypress	8	2 by 6 inches by 8 feet	Side and end uprights.
Do	8	2 by 6 inches by 7 feet	Cross pieces in frame.
Do	4	do	Roof frame.
Do	2	do	Base.
Do	2	2 by 6 inches by 8 feet	Do.
No. 1 pine	4	2 by 4 inches by 16 feet	Side frame bracing.
Do	1	2 by 4 inches by 12 feet	Do.
Do	2	2 by 4 inches by 16 feet	Rear-end frame bracing.
Do	1	2 by 4 inches by 6 feet	Do.
No. 1 oak	2	2 by 6 inches by 7 feet	Front-end frame bracing.
No. 1 pine	4	2 by 4 inches by 16 feet	Do.
No. 1 oak	2	2 by 4 inches by 11 feet	Lifting device.
No. 1 pine	2	2 by 4 inches by 7 feet	Do.
No. 1 oak	1	2 by 4 inches by 8 feet	Do.
No. 1 pine	4	do	Inside corner braces.
No. 1 oak	2	do	Support for coils.
No. 1 pine	2	2 by 4 inches by 2 feet	Roof frame bracing.
Do	2	2 by 4 inches by 14 feet	Brace inside chamber around base.
Do	2	do	Miscellaneous.
Clear cypress	9	1 by 3 inches by 14 feet	Inside strips.
Do	6	1 by 4 inches by 14 feet	Do.
Do	6	1 by 3 inches by 14 feet	Outside strips.
Do	2	1 by 4 inches by 7 feet	Do.
Do	4	1 by 7 inches by 8 feet	Do.
Do	4	1 by 7 inches by 7 feet	Do.
Do	8	1 by 6 inches by 8 feet	Do.
No. 1 pine	17	1 by 5¼ inches by 8 feet	Roof (tongue and groove).
Do	17	1 by 5¼ by 26 inches	Rear platform.
Clear cypress	1	1 by 12 inches by 10 feet	Instrument boards
Do	1	1 by 6 inches by 14 feet	Shelves.
Do	2	1 by 3 inches by 14 feet	Miscellaneous.
Do	1	1 by 4 inches by 14 feet	Do.
Do	4	¾ by 1 inch by 7 feet	To put under roof frame.
	Feet		
Miscellaneous	250	⅜ by 3 inches	Shimming.
Do	200	¼ by 4 inches	Do.

HARDWARE

Description	Pieces or quantity	Size	Use
	Number		
Carriage bolts	54	⅜ by 5 inches	
Do	12	½ by 8½ inches	
Do	4	⅝ by 9½ inches	
Do	36	⅜ by 6½ inches	
Do	12	½ by 7 inches	
Do	4	½ by 8 inches	
Do	40	⅜ by 8 inches	
Do	24	⅜ by 4 inches	
Do	40	⅜ by 2 inches	
Do	6	½ by 14 inches	Sled.
Machine bolts	4	½ by 8 inches	
Do	2	⅝ by 14½ inches	
	Gross		
Wood screws	1	No. 14, 2 inches	
Do	1	No. 10, 1½ inches	

TABLE 1.—*Materials for an individual refrigeration chamber, derrick, track, and sled*—Continued

HARDWARE—Continued

Description	Pieces or quantity	Size	Use
Wood screws—Continued.	*Number*		
Do	76	No. 16, 2 inches	
	Pounds		
Nails	23	8-penny	
Do	5	10-penny	
Do	2	3-penny	

IRON WORK

Description	Pieces or quantity	Size	Use
	Number		
Angle iron	1	1¼ inches by 14 feet 2 inches	Bent to fit 1 corner and 2 sides of base of refrigerator.
Do	1	1¼ inches by 14 feet	Do.
½-inch angle iron	2	3 by 5 inches by 7 feet 8 inches	Equalizers.
¼-inch angle iron	8	6 feet long	Bracing corners of derrick.
⅜-inch iron	2	2 by 23 inches	Bent to fit lifting device.
Do	2	2 by 37 inches	Do.
Do	2	2 by 30 inches	Support for rear platform.
Do	2	2 by 56 inches	Do.
Rods with turnbuckles	2	¾ inch by 8 feet	Equalizers.
Rods (threaded at each end)	5	5/16 inch by 7 feet	Internal bracing of walls and roof.
Rods	4	½ by 20 inches	Anchor rods.
Tierods with turnbuckles	4	⅝ inch by 10 feet 2 inches	Tightening cross braces.
Iron rods	4	⅝ inch by 5 feet 10 inches	Tightening knee braces.
Strap iron	4	5/16 by 2½ inches by 6 feet	Bracing sides of derrick.
Iron clevices with bolts	4	¾ inch	Equalizers.
Triangle pieces of iron	4	8 by 8 by 12 inches	Do.
Strap iron	16	¼ by 5 inches	Bent at right angles to support base of chamber (inside).
Do	2	⅜ by 4 inches by 3 feet	Sled.
Eyebolts	4	¾ by 9 inches	To hang chain hoists on.
Bands of iron	4	5/16 by 4 by 20½ inches	Bent to fit bottom of posts on derrick which have dolly pins welded into center of band at bottom, the dolly pins fitting into the carriages, which in turn fit tracks.
Iron wheels with 1-inch hubs	16	7½ inches	On carriage.
Shafting material	8	1 by 12 inches	Axles on carriage.
Iron with 2-inch angle on each side.	4	6 by 14 inches	Frame on carriage.
Galvanized iron	2	18 by 12 inches	Sled.
Do	1	8 feet ½ inch by 8 feet 6 inches	Roof covering.

PREPARATORY ARRANGEMENTS

The successful operation of the apparatus requires much forethought, careful preparation of the various details, and much patience and persistence. Furthermore, in order to secure results comparable to those produced in nature, the chambers must be operated during the night, as it is then that the untimely chilling and freezing temperatures occur in nature.

Some of the more important items to consider in conducting the experiments are: (1) Availability of dependable electric current; (2) dependable, efficient help; (3) choice of suitable locations in the field; (4) planting arrangement of experimental plots; (5) moving of derrick and chamber; (6) operation of the chamber; and (7) recording of the data.

ELECTRIC CURRENT

Dependable electric current, available where desired, is essential. Cable and lines can be run into the field to the location chosen. For operating from long lines, it is essential that the wires used be heavy enough not to cut down the voltage too much, because proper voltage is necessary for the satisfactory operation of the thermostats and motors. Heavily insulated no. 8 wires run from the transformer have been found satisfactory. The transformer should be placed as close as possible to the experimental field plots. There must be adequate electric energy to handle the maximum load at any time.

HELP

Dependable efficient help is equally as essential as dependable electric current. Much of the work must, of necessity, be done under direction, and some one little thing done wrongly might spoil the results of an entire experiment or whole series of experiments. The equipment is rather complex and delicately adjusted. Therefore, it is necessary to handle it carefully and intelligently. Too much emphasis cannot be placed on the necessity of dependable help.

EXPERIMENTAL FIELD PLOTS

LOCATION

The experimental field plots should be located on as uniform soil as possible. Very uniform soil is especially important, because it is obviously impossible to use large numbers of mature corn plants in identical stages of development at any one time. It is also distinctly advantageous to have the plots on level land, as the derricks and chambers are so heavy that it is very difficult to move them uphill.

PLANTING ARRANGEMENT

The chambers previously described are designed to cover four hills of corn spaced about 3 feet apart each way, as shown in figures 1 and 18. Accordingly the plantings are made in blocks of four hills each (figs. 18 and 19, A), or in 3-foot rows, with one kernel in a place. Different strains of corn or different soil treatments, or both, may be placed in the same block (fig. 19, B and C), so that the plants in the same blocks may be identically exposed. It will be noted that, in each series, the blocks, 6 feet apart, are arranged in groups of 3 with a 15-foot space between the groups (fig. 18). These 15-foot spaces are used (1) for parking the chambers when not in use and (2) for moving the derricks and chambers to the next series at any point. An 8-foot space is left between the different series for working space. However, corn may be planted solid and the alleys and parking spaces cut out later (fig. 2).

OPERATION OF CHAMBER

METHOD OF MOVING CHAMBER

For moving the chamber, the derrick and sled, previously described, are necessary. The derrick may be built in the field or, if

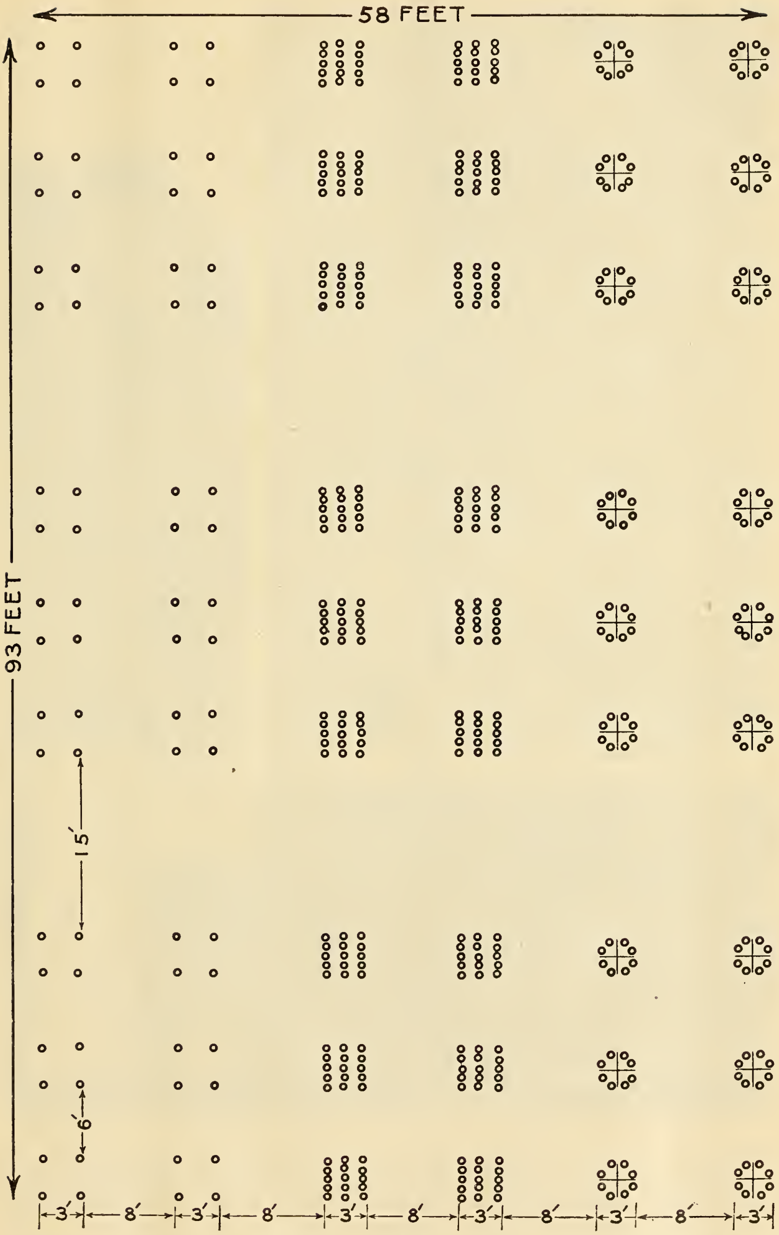


FIGURE 18.—Planting arrangements for experimental plots; the small circles indicate hills or individual plants.

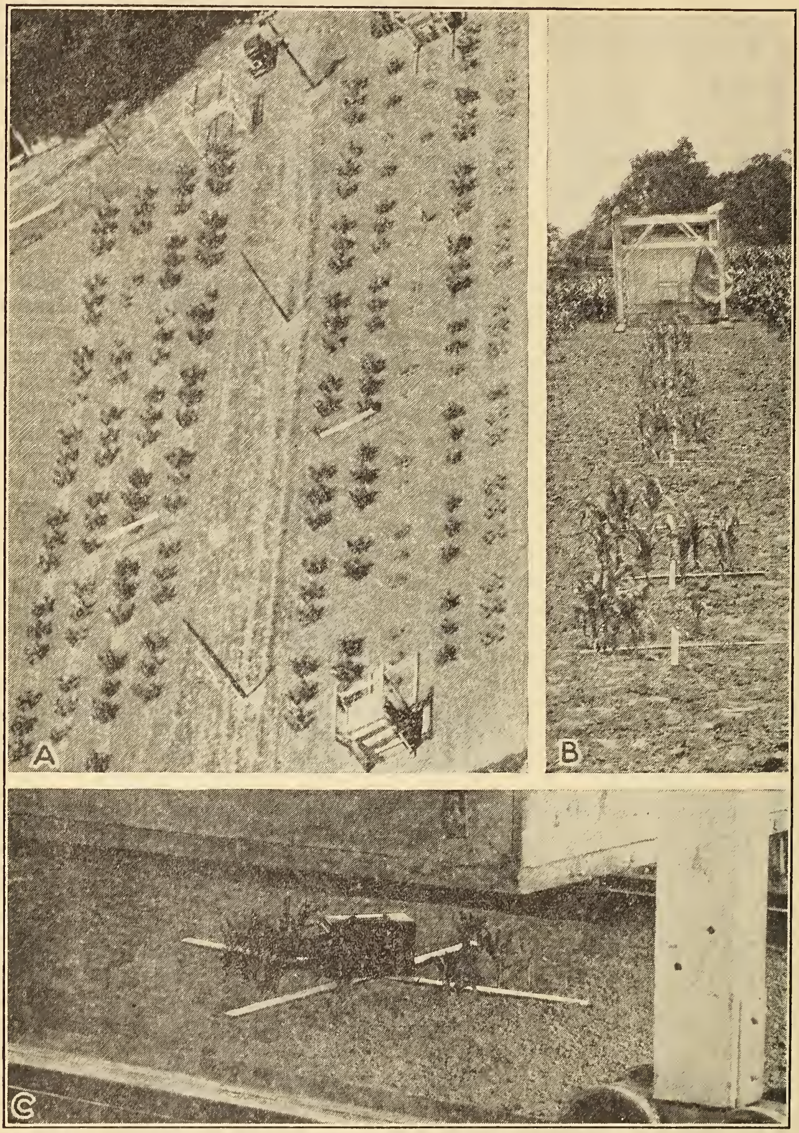


FIGURE 19.—Experimental field plots in which refrigeration chambers are used: A, Aerial view (courtesy of the Bloomington Daily Pantagraph); B, closer view of the third series from right in A; C, chamber being lowered over one of the blocks shown in B, with air thermograph in place, and white cross marking tops of partitions that extend 15 to 18 inches into the soil and separate the different soil treatments in each quarter of the block.

built elsewhere, it may be dismantled, moved to the field by truck, and set up there.

The chamber may be moved to the field by truck, where, by means of the derrick and chain hoists, it is lowered to the ground near the plants to be studied, or to the sled, on which it may be moved to the desired place, as shown in figure 11, B and C.

In order to move the derrick and chamber from one location to another in the experimental plots, the chamber is raised from the ground by means of the derrick and hoists, and then the derrick and chamber are pushed on the track to whatever position desired. Four men can handle the chamber (fig. 1), one man for each chain hoist in raising and lowering the chamber, and one man for each derrick post in moving. Two men can easily carry a track plank and place it as desired (fig. 10).

In making right-angle or other turns, the derrick is jacked up, one side at a time, the track is turned in the desired direction, the carriages are turned, and the derrick is let down on the track again in the new position. Sometimes two chambers can be moved very advantageously on the same track, when both are operated on the same series of plots, as shown in figures 2 and 17.

Long moves in an experimental plot, or moves from one experimental plot to another in the same field, may often be made more easily by using the sled and tractor, as shown in figure 11, than by using the tracks.

METHOD OF USING CHAMBER

When the chambers are in position over the plants, the thermocouples inserted and properly placed, the thermographs adjusted, and everything ready, including a record of operations and sheets for recording data, the refrigeration units are started. The thermographs are then watched to see that the temperatures in the chambers are going down as desired. When a sudden drop in temperature is being effected by using all the refrigeration units at full capacity, distance-reading thermographs, because of their lag, do not always indicate the exact temperatures within the chambers. In order to stop the drop in temperature at the desired point, there is much advantage in using the potentiometer to measure the temperatures at different places within the chambers and within the plant tissues so that the temperatures may not drop lower, or warm up sooner, than has been planned. The lag of the distance-reading thermograph and the greater sensitivity of the thermoelectric equipment in measuring temperatures is shown in figure 20. The record of temperatures obtained by the thermoelectric method, shown in figure 20, is the average of the temperatures in each of the four corners of the chamber at points near the ears of corn in each of the four hills.

Chambers equipped with four refrigeration units are operated more advantageously than those with only one, as in the former the temperatures are under better control. For example, in starting, all four refrigeration units may be operated until the temperature begins to come down rather rapidly. Then, if it is desired to bring down the temperatures gradually, some of the units may be turned off so as to get gradual lowering of the temperature in the chamber, as shown in figure 21. If a rather sudden drop of temperature is planned, the chambers may be cooled thoroughly for several hours before they are put in position over the plants and then, after they have been placed, all four units may be left in operation until the desired temperatures are obtained. The thermostats may be adjusted to turn off the motors of the units equipped with thermostats when the desired temperatures are reached. As the temperatures rise again, the thermostats should turn on the refrigeration units equipped with them and keep those refrigeration units in operation until the temperatures are again brought down to the desired point.

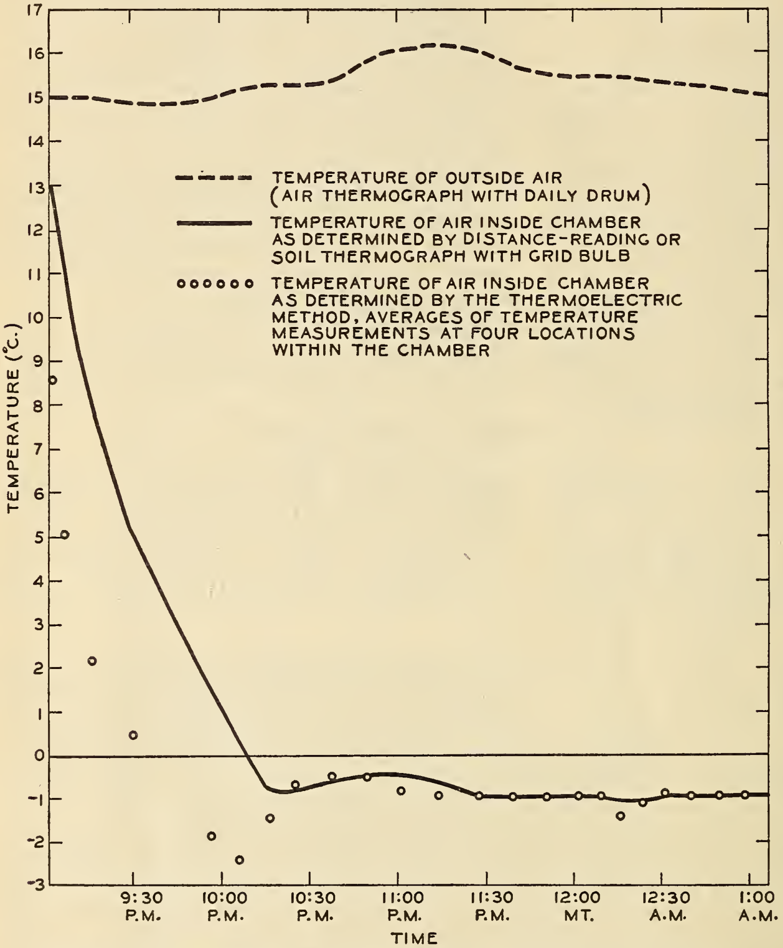


Figure 20.—Air temperatures outside and inside of refrigeration chamber.

While the equipment is automatic, it is necessary to watch it more or less constantly throughout any period of operation and to make adjustments from time to time. For the most part, the heat leakage of each chamber under any given set of conditions is a rather constant factor which can be approximately balanced by the manually controlled refrigeration units. By means of the thermostatic control, with everything favorable, the desired temperatures have been held within ±1° C. (fig. 22). When thermostatic control has been supplemented by manual control of both electric current and refrigerant and frequent temperature readings have been made by the thermoelectric method, the variation of temperature has been reduced for a period of several hours to ±½° C. (fig. 23). Damp gunny sacks or cloths hung over the baffles and on the inside walls of the chamber help in maintaining a high relative humidity of the air within the chamber when needed. A fine spray of water may be directed against these sacks or cloths at intervals by means of a hand-power sprayer on the outside, the short tubing on the sprayer being replaced by one of sufficient length to extend through the wall of the chamber.

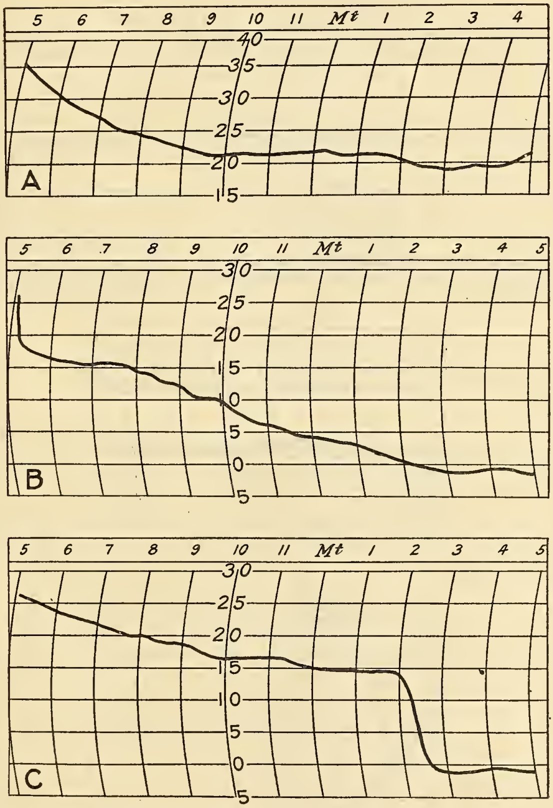


FIGURE 21.—Records of air temperatures, night of June 17, 1930: A, Outside of refrigeration chamber; B, inside of refrigeration chamber gradually cooled to 0° to −1° C.; C, inside of refrigeration chamber cooled gradually to about 15° and then cooled rapidly to 0° to −1°.

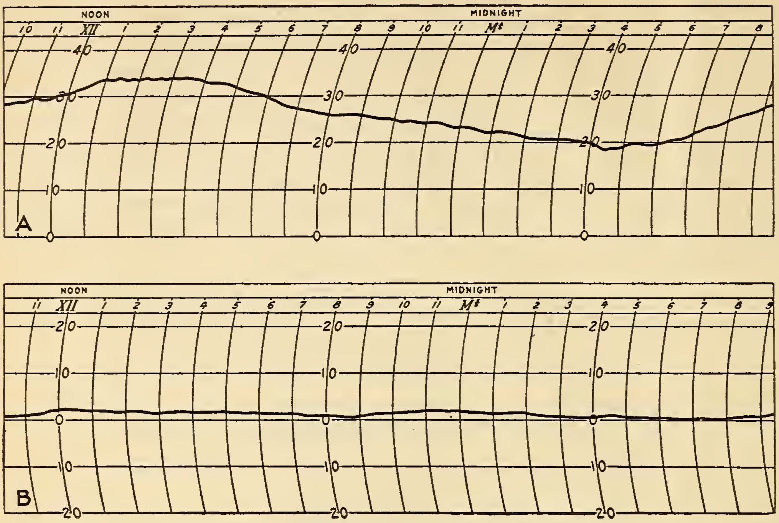


FIGURE 22.—Records of air temperatures, October 13, 1930, and following night: A, Outside of refrigeration chamber; B, inside of refrigeration chamber held at just above 0° C.

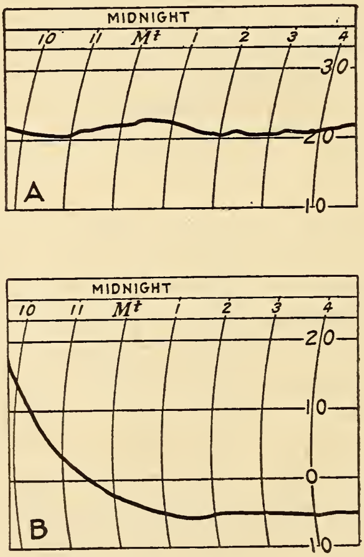


FIGURE 23.—Records of air temperatures on night of October 6, 1930: A, Outside of refrigeration chamber; B, inside of refrigeration chamber artificially cooled to −5° C. in 4 hours and maintained at that temperature for 4 hours.

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